B. Tech thesis on

Improving MAC Layer Performance in WLAN

For partial fulfillment of the requirements for the degree of

Bachelor in Technology

In

Computer Science and Engineering

Submitted by:

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Under the guidance of:

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CERTIFICATE

This is to certify that the Thesis entitled, "**Improving MAC Layer performance in WLAN**" submitted by **Nitish Kumar Panigrahy** and **Manat Kanher** in partial fulfillment of the requirements for the award of **Bachelor of Technology Degree** in **Computer Science and Engineering** at the **National Institute of Technology, Rourkela** is an authentic work carried out by them under my supervision.

To the best of my knowledge and belief the matter embodied in the Thesis has not been submitted by them to any other University/Institute for the award of any Degree/Diploma.

Prof. Suchismita Chinara
Department of Computer Science and Engineering
National Institute of Technology, Rourkela.

ACKNOWLEDGEMENT

This project in itself is an acknowledgement to the inspiration, drive and the technical assistance contributed to it by many people. It is with great pride and satisfaction that we present our thesis under "Research Project" paper during our final year.

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Last but not the least we thank our parents and family members for their constant support and motivation which helped believe that we can successfully complete this project.

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Abstract

WLAN stands for Wireless Local Area Network. Now a days wireless technology have been widely implemented starting from home to educational institutes. So improving its performance is highly required. To increase the performance of the network some modifications can be made in MAC layer. So MAC layer has been studied thoroughly and some modification was done on back off algorithm.

Some of the key concepts of our project are:

Distance and performance: If distance between station and the AP varies then also performance varies.

Scalability & Collision: If number of nodes increases in a network then its performance decreases due to heavy traffic.

WLAN mechanisms: It may be Basic Access or RTS-CTS i.e. either directly sending the data or after RTS-CTS handshake.

Back-off algorithms: There are mainly three back-off algorithms. EIED, MILD & BEB.

EIED was compared with BEB wrt various packet arrival rates (eight) for RTS-CTS mechanism. Previous work has been done on Basic access mechanism. Some results were proposed by taking various combinations of values of EIED algorithm.

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

1.1 Introduction:

Wireless local area network (WLAN) has been an integral part of life now a days. It requires no physical connection. Improving its performance is a much difficult task. The whole WLAN mechanism has been studied and IEEE802.11b standard was followed. Improvement of performance of MAC layer was of more concern. MAC layer have different modules out of which Back-off algorithms were focused. Some range of values of the existing algorithm were tried to be figured out for which good performance was expected.

1.2 Motivation:

In the existing back off algorithm the range of values are not specified correctly. Also the work has been done on RTS-CTS mechanism not on basic access mechanism. Previous work has been done on basic access mechanism. But as according to [2] it has been found out that RTS-CTS is better than basic access in many cases. So RTS-CTS mechanism was selected.

1.3 Organization:

Thesis is organized into five chapters. Chapter one includes the introduction, motivation and organization of the thesis. Chapter two includes some of the basic properties of the WLAN concepts, MAC access methods, different carrier sensing mechanisms etc. Chapter three includes the WLAN architecture and some of the key concepts of our project. Chapter four gives us the simulation and the simulation results. Chapter five includes the conclusion.

CHAPTER 2

2.1 WLAN

Wireless local area network (WLAN) uses electromagnetic waves to send information. It transmits data without any physical connection. WLAN supports same capabilities and speed of a wired network. In a wireless network different stations may be connected with an access point or it can be a adhoc network. The data transmitted in a WLAN is placed on a radio wave carrier. Carrier modulation is done to demodulate accurately the received signal. Radio waves are transmitted at various frequencies so that they can be transmitted without interfering with each other because interference degrades the quality of signals drastically. Receiver has a filter circuit in it so that it can be tuned to the desired frequency while rejecting all other frequencies.

2.2 SYSTEM ARCHITECTURE

There are two types of system architecture in a wireless network

- Ad Hoc or Peer to Peer network.
- Infrastructure or client-server network.

2.2.1 Ad Hoc or Peer to Peer network

In adhoc mode nodes are interconnected with each other. There is no central data base with which nodes are connected. Mobile Adhoc Networks(MANET),Wireless Sensor Network(WSN) and many more are branches of this network. This network is a very important area of research now a days. It is also known as Independent Basic Service Set. We need to focus on the range of each station.

2.2.2 Infrastructure or client-server network

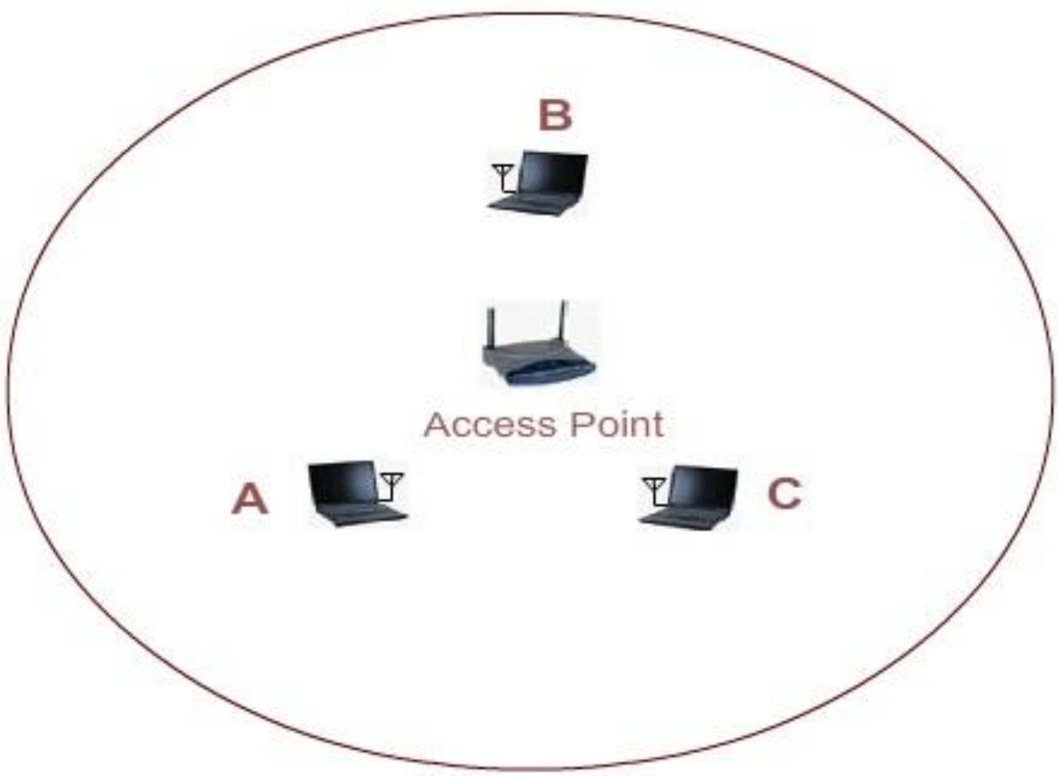

Fig 1 : Infrastructure Network

Above figure illustrates the infrastructure mode in which we have a central station (AP) which receives data from one station and forwards it to other. Normally an Access Point (AP) acts as the server. Sometimes Ethernet is also connected to AP. At this stage AP is considered as bridge.

In the project the infrastructure network i.e. an Access Point with few stations was widely studied.

Sometimes the infrastructure mode is also known as Basic Service Set consisting of the following components.

- Wireless Lan stations
- Access Points

As specified by TCP/IP model WLAN also has its five layers. Out of which the data link layer (specifically MAC) was the area of concern.

2.3 MAC ACCESS METHOD

MAC layer is a part of the data link layer. When several nodes are trying to access a shared medium it performs The main work of MAC is to allocate the channel among various stations so as to minimize collisions. It can be considered as a bridge between Logical Link Control and Physical Layer of the network. Wireless MAC is implemented with the help of the following functions.

2.3.1 Distributed Coordination Function (DCF)

This is fundamental mechanism to access the medium. DCF follows Carrier Sense Multiple Access Avoidance (CSMA/CA) standard. In CSMA/CA the station senses whether the medium is idle or not before any transmission. RTS/CTS is an optional extension to CSMA/CA. RTS-CTS introduces a virtual carrier sensing concept which further reduces the probability of collision. In Distributed co-ordination Function, all static nodes contend for the medium and transmit data. For transmission of packets DCF has introduced two techniques. One is a two way handshake known as Basic Access Mechanism in which a successful transmission is followed by a the transmission of a positive acknowledgement by the receiver. The other technique is an optional four way handshake known as request-to-send/clear-to-send (RTS/CTS) in which the station has to contend for the channel and acquire it by RTS frame. Then receiver sends CTS (clear to send) signal to the sender. If sender successfully receives CTS then the actual data transmission takes place and then acknowledgement. Though delay is the main issue with RTS-CTS still with a very loss percentage as compared to basic access in some cases it is used. The DCF we discussed is an asynchronous service that is a channel is not assigned to a particular station for a particular period of time. For synchronous the following function was adopted.

2.3.2 Point co-ordination function (PCF)

Point co-ordination function provides synchronous service for implementation of CSMA/CA. Contention free frames are being transferred with the help of a Point Coordinator (PC) which is chosen among the stations. The Access Point acts as a PC. Before transmitting any data AP chooses a time period known as Contention free Period (CPF) and polls all the stations during this period. All stations transmit their data according to their turn and thus collision is completely avoided. PCF is not popular but sometimes it helps out a lot.

2.4 INTERFRAME SPACES

It can be defined as the parameters used to prioritize a packet during wireless transmission when multiple nodes are contending for data transmission. There are three types of Inter Frame spaces:

- Short Inter Frame Spacing (SIFS)
- PCF Inter Frame Spacing (PIFS)
- DCF Inter Frame Spacing (DIFS)

When number of nodes are transmitting data SIFS gets the highest priority followed by PIFS and DIFS is given the last priority.

2.4.1 SHORT INTERFRAME SPACING

SIFS has the highest priority among the different inter frame space used. This can be defined as the time interval between transmission of the data frame and the arrival of its acknowledgment. The radio link is at first being accessed by the station having this type of information. SIFS is fixed and calculated so as to make the transmitting station able to switch between the transmitting mode and receiving mode and decoding becomes easy. The SIFS value depends upon the transmission technology. There are three such technologies. They are Direct Sequence Spread Spectrum (DSSS), Frequency Hopping Spread Spectrum (FHSS) or Infra Red (IR).

DSSS technology as per IEEE 802.11b standard was used in the project. The value of SIFS in DSSS is 10µs.

2.4.2 PCF INTER FRAME SPACES (PIFS)

The time-bound services mainly use PCF Inter Frame Spacing (PIFS). They wait for this time period. To gain access to the medium before any station Access Point waits for the PIFS duration if AP is being enabled by PCF. PCF Inter Frame Spacing is used during contention free operation. After PIFS duration stations which have some packets to send can transmit their packets. All these operation takes place during contention period. Thus contention based traffic is being avoided. In polling Access point knows the status of the nodes and the process of polling takes place in the Access Point. In polling periodically the medium is being checked for availability by sending radio signals. If medium is found to be idle then the current node is allowed to transmit the data else it has to wait. PCF has not been widely implemented in practice.

PIFS duration can be calculated as:

PIFS=PIFS + slot time

2.4.3 DCF INTER FRAME SPACING (DIFS)

The minimum idle time of the medium for contention based traffic is known as DIFS. Stations check the medium for DIFS time interval. If the medium is found idle during this period then they start transmitting the data. But if it is found busy then they defer their transmission by some amount of time.

DIFS depends upon the physical transmission technology used. For the project in DSSS technology **DIFS is 50μs**.

2.5 Carrier Sensing:

In this mechanism station will not directly send the data. It will sense the carrier and if it is found to be idle the it will send the data else it will defer its transmission. This is used to avoid collision but collision is not completely eliminated by this process. If no one is transmitting the sender sends the data immediately but if any other node is transmitting then the sender has to wait till the transmission is complete.

Carrier sense is a part of medium access control (MAC) layer. There are two types of carrier sensing mechanism

- Physical carrier sensing
- Virtual carrier sensing

2.5.1 Physical carrier sensing

Before transmitting a packet a station should know the channel conditions. This is being provided by physical carrier sensing. Sampling of the energy levels are done by the station and it transmits the packets only if it gets hardware signal clear channel assessment (CCA) in the physical layer. If the reading is below the carrier sensing threshold then the CCA signal is generated. This carrier sensing mechanism is provided by hardware and very costly to build.

2.5.2 Virtual Carrier Sense Mechanism

Network Allocation Vector (NAV) is the base of virtual carrier sensing. The control frames (RTS/CTS) in MAC layer is used to implement NAV. The time for which medium will be reserved is being indicated by the NAV timer. RTS/CTS frame carries NAV duration value. Stations which are about to transmit the data set NAV to the time they will reserve the medium. Other stations update their NAV and countdown it to zero. When NAV is non-zero medium is considered to be busy. When NAV is zero, it indicates that the medium is idle. So stations that have data to send, contend for the medium.

RTS-CTS mechanism was adopted in order to implement virtual carrier sensing.

2.6 NETSIM

Netsim is a network simulator which performs the simulation over any given network to give us desired output in terms of throughput, delay, number of packets collided, Effective utilization, number of frames discarded, total payload and many more. It has its features to customize user codes to implement different networking protocols according to user requirement. It also has the analytics module which helps in comparing performance of different networks. As a whole NETSIM is a wonderful tool to study different networking aspects.

CHAPTER 3

3.1 Network Performance

The two main characteristics of WLAN which affects its performance the most is

- Distance from AP
- Number of nodes

Both the parameters have been studied below.

3.1.1 Distance from AP and Network Performance

Using NETSIM, a network simulator, the distance between node and AP was varied up to 100m. The following results were obtained.

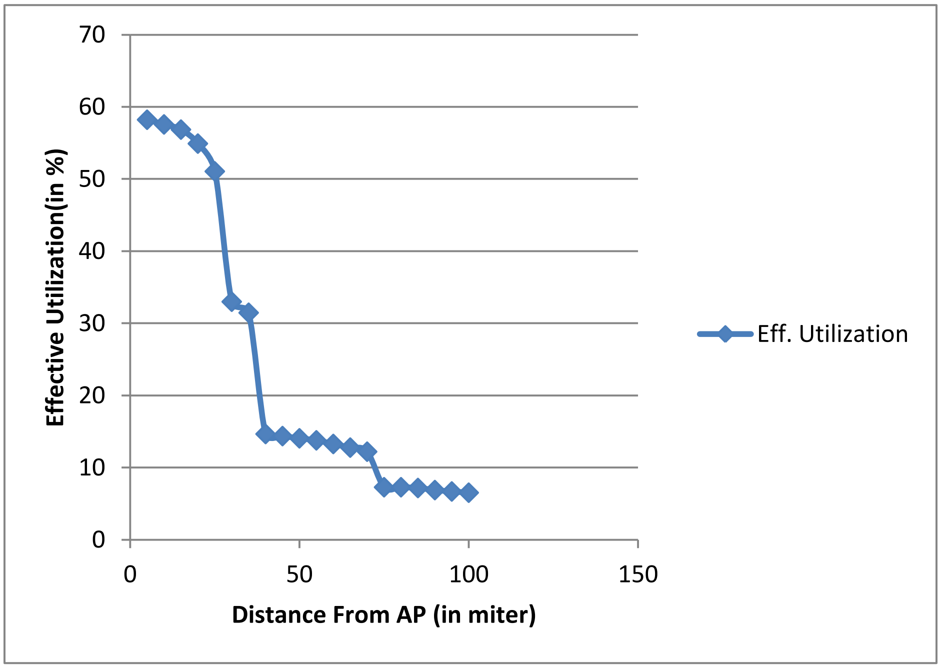

Fig 2: Distance vs. Effective Utilization

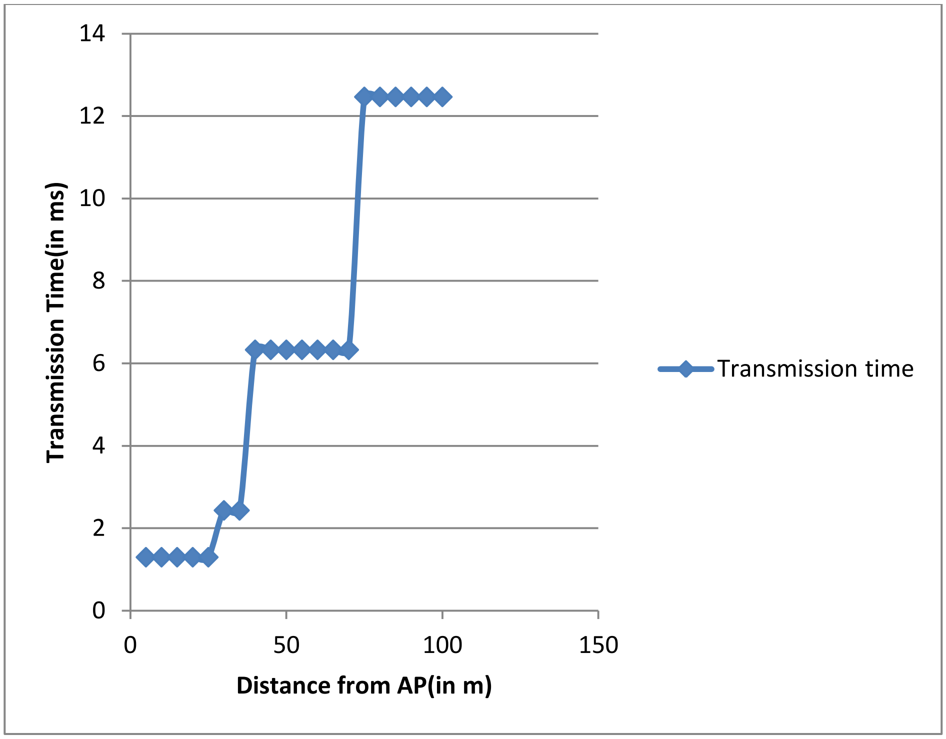

Fig 3: Distance vs. Transmission Time

Inferences

Receiver performance varies with distance from AP as follows.

Received Power (in dBm)	Data Rate (in Mbps)
<-70	1
<-65 & >-70	2
<-60 & >-65	5.5
>=-60	11

Table 1: Received Power and Data Rate Relation

With increase in distance from AP utilization decreases because received power decreases. Utilization is directly proportional to received power. The transmission time increases Because transmission time is inversely proportional to Data Rate. The more the received power more will be the Data rate and hence lesser will be the transmission time. Thus four different data rates of IEEE 802.11b standard were obtained.

3.1.2 **Scalability & Network Performance**

With the help of NETSIM we compared the network performance with number of stations as follows.

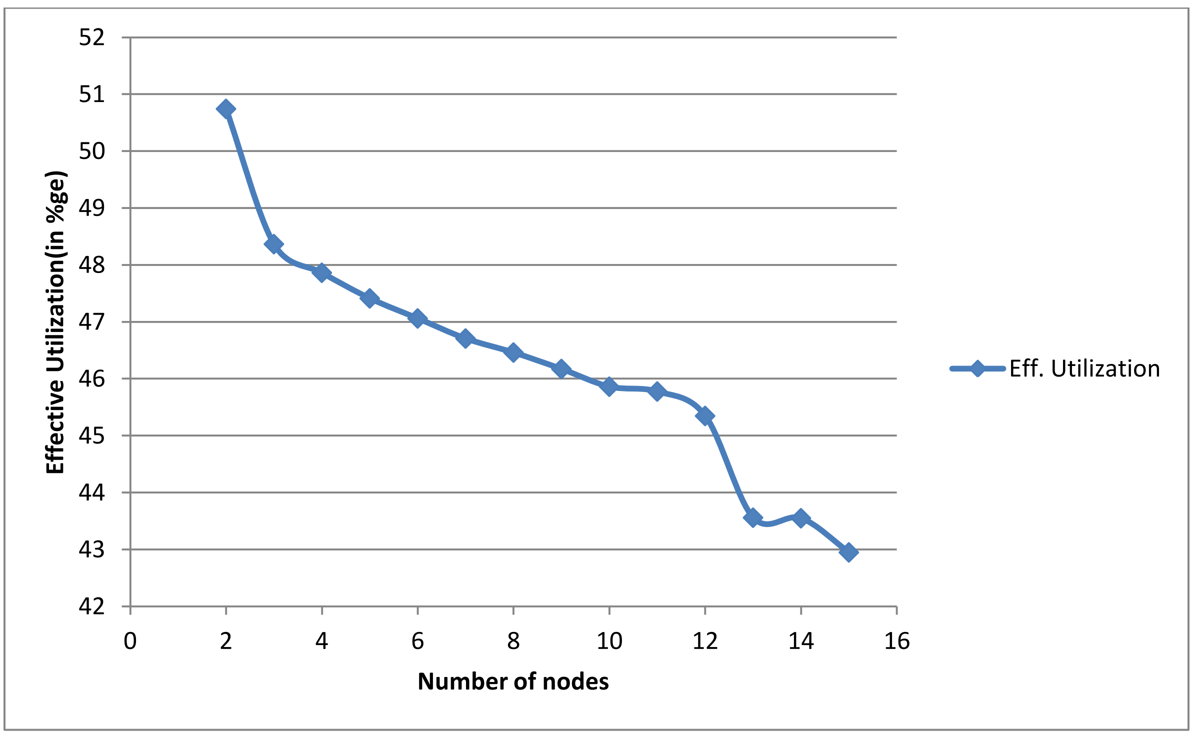

Fig 4: Number of nodes vs. Effective Utilization

Inferences From Scalability

- As the number of transmitting nodes increases effective utilization decreases.
- As more nodes generate traffic there is greater load on the network with more nodes trying to gain medium access.
- This leads to increased collisions. Since more time is wasted on collisions and retransmissions effective utilization is reduced.

3.2 WLAN Mechanisms

There are mainly two mechanisms in WLAN. They are basic access mechanism & RTS-CTS mechanism. In RTS-CTS first handshaking is done between station and AP then actual data is sent but in Basic Access we directly send the data.

A comparison between the two mechanisms are given below.

Slno.	Size of Data (in bytes)	Basic Access Loss(in %)	RTS-CTS Loss(in %)
1.	1500	12.548	2.100
2.	65	3.695	.975

Table 2: Basic Access vs. RTS-CTS (loss)

Slno.	Size of Data (in bytes)	Basic Access Delay(in s)	RTS-CTS Delay(in s)
1.	1500	4.654	4.707
2.	65	4.071	4.563

Table 3: Basic Access vs. RTS-CTS (delay)

Inference

When data size was 1500 bytes i.e. a huge size loss %ge was greater in basic access mechanism as whole of 1500 bytes of data was lost in it but in RTS-CTS mechanism only 20 bytes of RTS frame is lost. So loss is less in RTS-CTS.

But when data size is 65 bytes even a loss of 20 byte RTS frame also counts. So difference in loss is less between two mechanisms.

But delay is less in basic access mechanism as we don’t have to send RTS-CTS frame which is purely an extra overhead. For a lower size data difference between delays is even more because for a low size data also we have to send equal size control frames.

3.3 WLAN ARCHITECTURE

A flow chart of the WLAN architecture has been represented as follows.

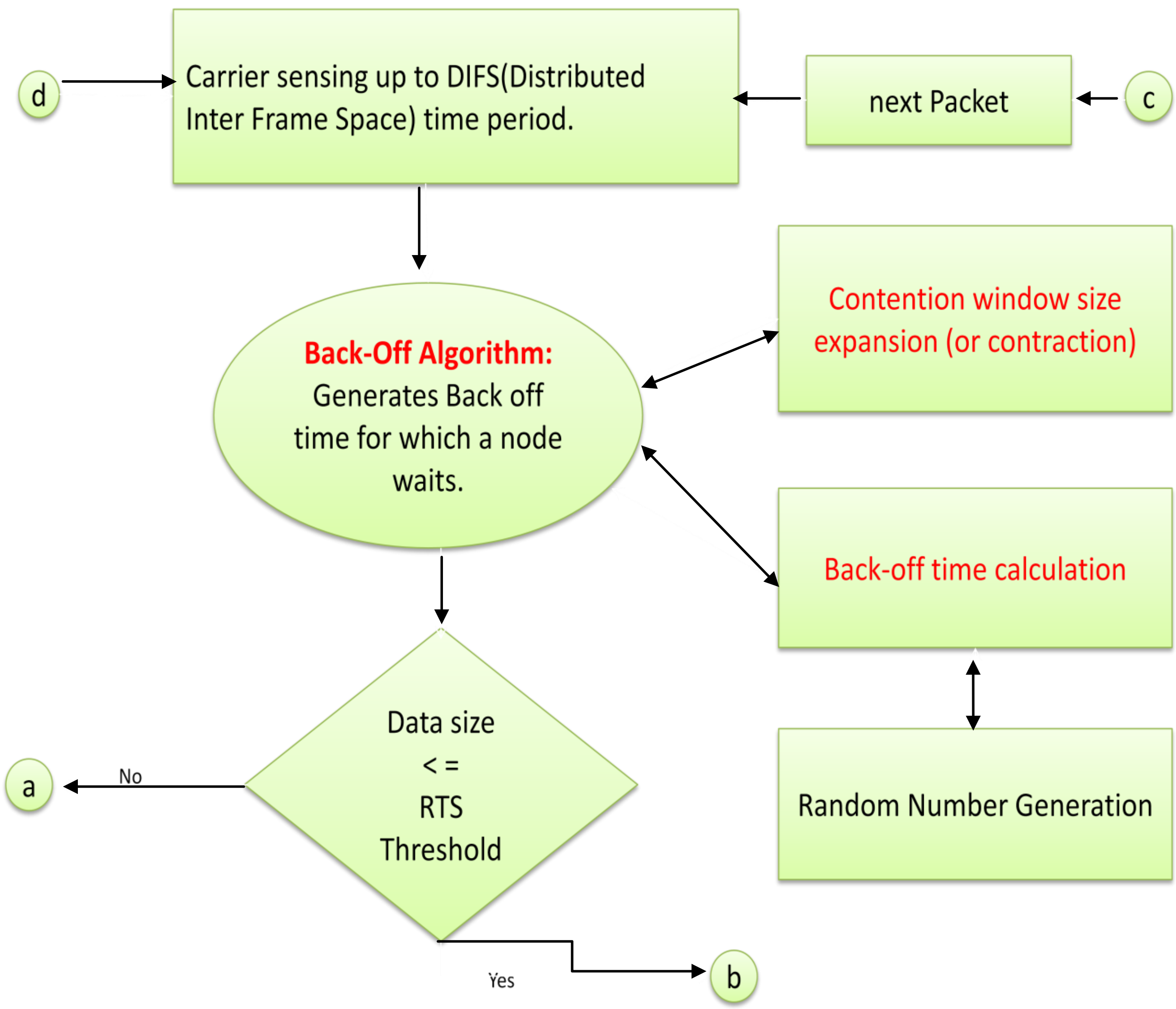

Fig 5: WLAN Architecture (I)

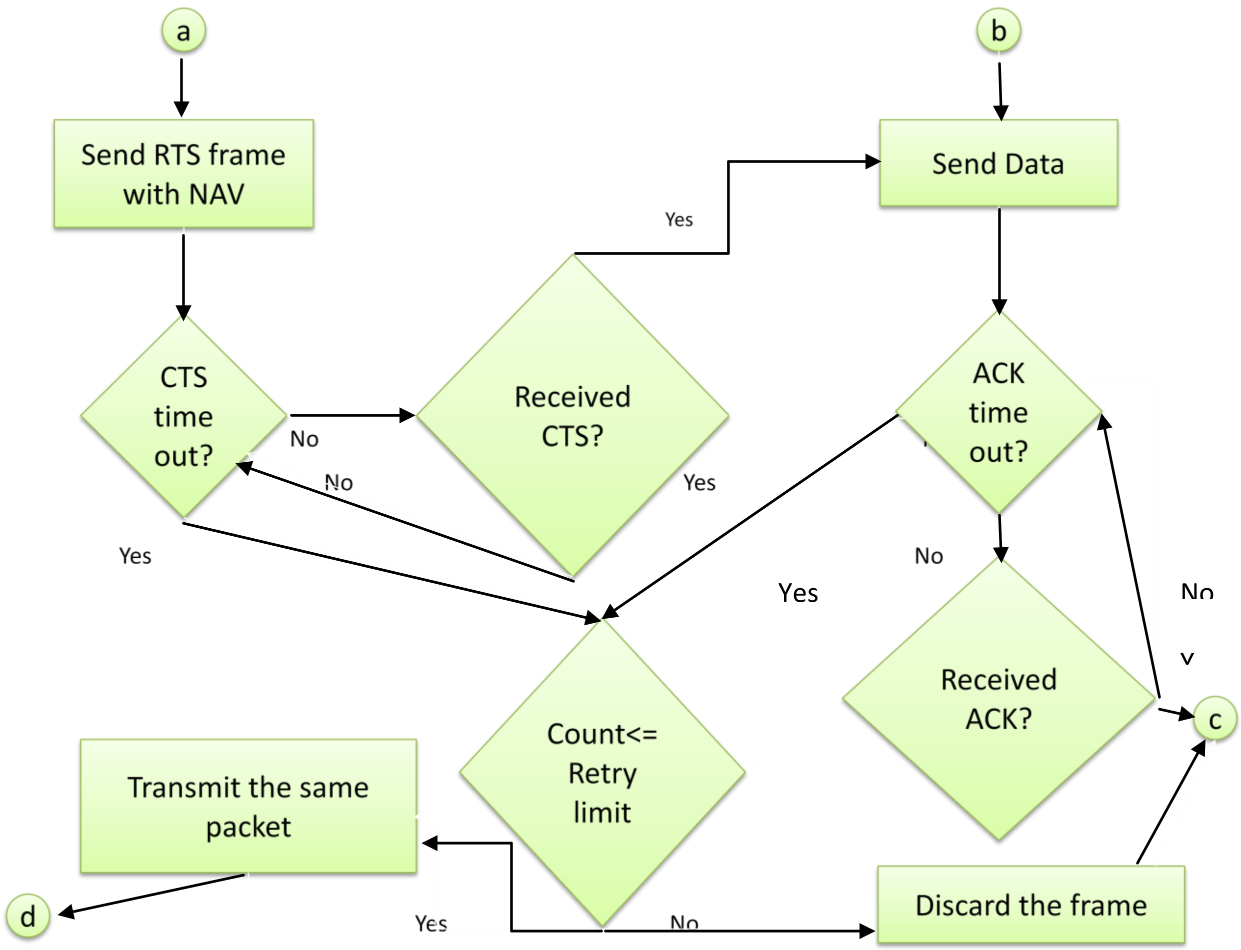

Fig 6: WLAN Architecture (II)

In the above architecture we are mainly concerned on the back off algorithm which is described as follows.

3.3.1 Back-Off Algorithm

- Back-off time is chosen randomly from the interval [0, **cw**] where cw represents the contention window.
- For each transmission **cw** is expanded (or contracted).
- If the medium idle, then stations' Back off Time will be decremented.
- If the medium gets busy the back-off time decrementation is paused and is resumed when the medium has been sensed idle.

3.3.2 Contention Window Expansion

The contention window can be expanded in 3 of the following ways.

- BEB: (Binary Exponential Back off)
  - **Successful Transmission: cw=cwmin**
  - **Collision: cw=cw * 2**
- MILD(Multiple Increase Linear Decrease)
  - **Successful Transmission: cw=cw-1**
  - **Collision: cw=cw * 1.5**
- EIED(Exponential Increase Exponential Decrease)
  - **Successful Transmission: cw=cw/rd**
  - **Collision: cw=cw * ri**

3.4 Existing Work

There has been work on implementation of different back-off algorithms for basic access mechanism. The results are as follows.

- BEB is being outperformed by EIED for (ri,rd)={(2,2),(2√2, 2√2), (2,$2^{1/2}$),(2, $2^{1/4}$)} both in delay and throughput.
- MILD performs well in heavy traffic but for lower n it is being outperformed by both BEB and EIED.

3.5 Proposed Work

- EIED with BEB were compared wrt various packet arrival rates (eight) for RTS-CTS mechanism using **NETSIM**.
- RTS-CTS mechanism was chosen due to [2].
- Few results were proposed by taking various combinations of values of ri and rd in EIED algorithm.

CHAPTER 4

4.1 Simulation Parameters

- Data Size: 1472 Bytes
- Interarrival Time: 1000μs to 20000μs
- Mechanism: RTS-CTS
- Number of nodes: 5 , 15 & 25
- Retry Limit: 7

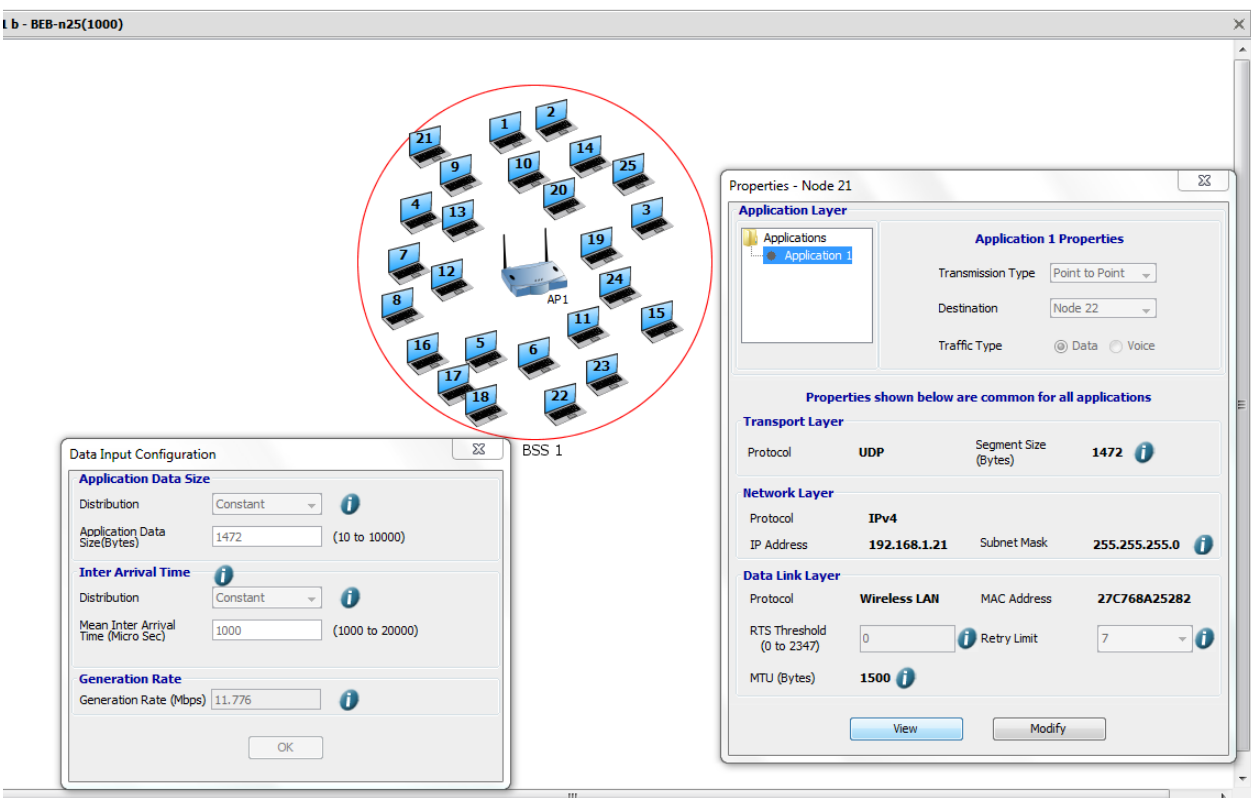

Fig 7: Simulation Snapshot

4.2 Simulation Results

The performance of BEB vs. EIED was compared for ri=5 and rd=7 as follows for all three cases.

Here T: Throughput & D: Delay.

Data Size: 1472 bytes, n=5 , RTS-CTS

Packet Arrival Rate (packet/sec)	Packet Arrival Rate (μsec/packet)	BEB	MILD	EIED Ri=5,Rd=7
50	20000	T=2.94 D=0.2704	T=2.39 D=0.231	T=2.93 D=0.238
67	15000	T=3.92 D=0.839	T=2.48 D=0.652	T=3.85 D=0.849
83	12000	T=4.28 D=1.225	T=3.81 D=0.853	T=4.28 D=1.173
100	10000	T=4.34 D=1.761	T=3.51 D=1.268	T=4.40 D=1.166
125	8000	T=4.27 D=2.390	T=3.87 D=1.105	T=4.37 D=2.319
250	4000	T=4.33 D=3.593	T=2.61 D=3.477	T=4.45 D=3.59
500	2000	T=4.33 D=4.211	T=4.71 D=3.38	T=4.24 D=4.183
1000	1000	T=4.33 D=4.517	T=4.71 D=3.569	T=4.24 D=4.496

Table 4: Comparison of different back off algorithms (for n=5)

Data Size: 1472 bytes, N=15, RTS-CTS

Packet Arrival Rate (packet/sec)	Packet Arrival Rate (μsec/packet)	BEB	MILD	EIED Ri=5,Rd=7
50	20000	T=4.61 D=2.465	T=4.10 D=2.488	T=4.74 D=2.35
67	15000	T=4.69 D=3.055	T=4.15 D=3.048	T=4.78 D=2.971
83	12000	T=4.73 D=4.419	T=3.94 D=3.715	T=4.83 D=3.367
100	10000	T=4.62 D=3.735	T=3.94 D=715	T=4.79 D=3.562
125	8000	T=4.59 D=3.951	T=4.21 D=3.838	T=4.91 D=3.738
250	4000	T=4.65 D=4.483	T=4.02 D=4.357	T=4.8 D=4.443
500	2000	T=4.72 D=4.733	T=4.10 D=4.568	T=4.86 D=4.693
1000	1000	T=4.72 D=4.735	T=4.11 D=4.681	T=4.87 D=4.103

Table 5: Comparison of different back off algorithms (for n=15)

Data Size: 1472 bytes, N=25, RTS-CTS

Packet Arrival Rate (packet/sec)	Packet Arrival Rate (μsec/packet)	BEB	MILD	EIED Ri=5,Rd=7
50	20000	T=4.71 D=3.396	T=4.57 D=2.944	T=4.85 D=3.262
67	15000	T=4.63 D=3.825	T=4.47 D=3.784	T=4.93 D=3.673
83	12000	T=4.66 D=4.057	T=4.38 D=4.017	T=4.88 D=3.976
100	10000	T=4.72 D=4.174	T=4.48 D=4.121	T=4.87 D=4.103
125	8000	T=4.73 D=4.339	T=4.21 D=4.272	T=4.87 D=4.281
250	4000	T=4.70 D=4.684	T=4.02 D=4.567	T=4.89 D=4.654
500	2000	T=4.70 D=4.844	T=4.50 D=4.723	T=4.89 D=4.834
1000	1000	T=4.71 D=4.924	T=4.50 D=4.801	T=4.87 D=4.103

Table 6: Comparison of different back off algorithms (for n=25)

Following graphs were plotted with respect to throughput and delay for different network size.

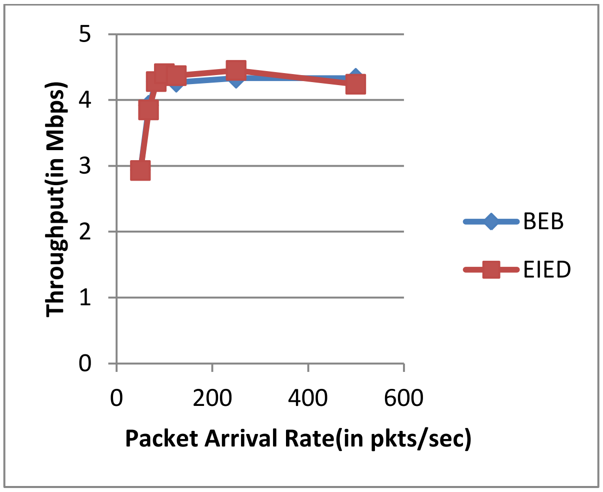

Fig 8: Packet Arrival Rate vs. throughput (n=5)

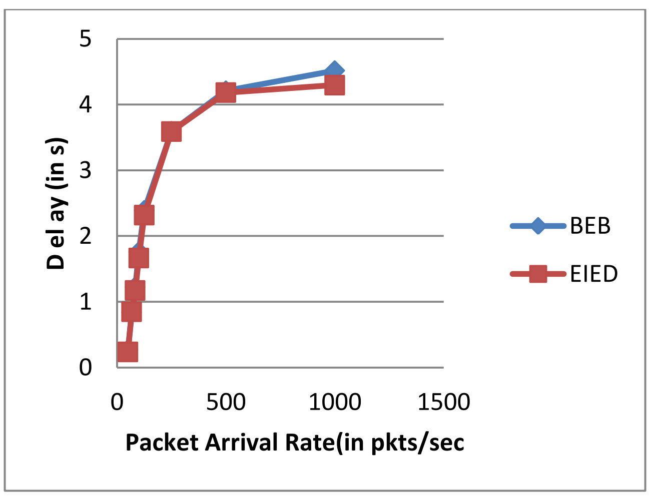

Fig 9: Packet Arrival Rate vs. delay (n=5)

$n=5$, $r_i=5$ and $r_d=7$

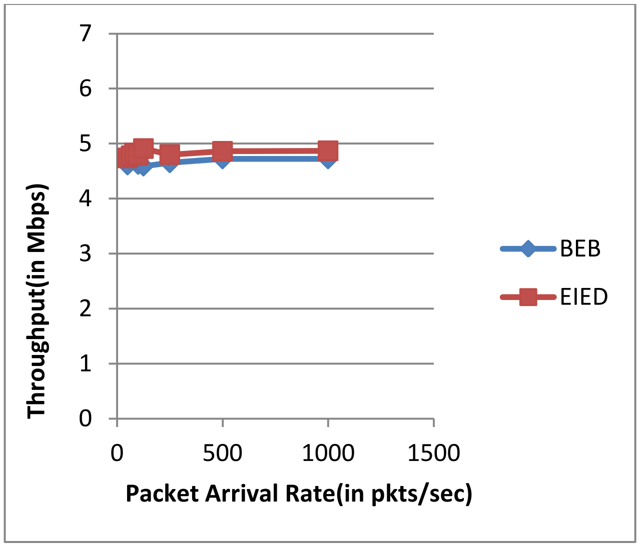

Fig 10: Packet Arrival Rate vs. throughput (n=15)

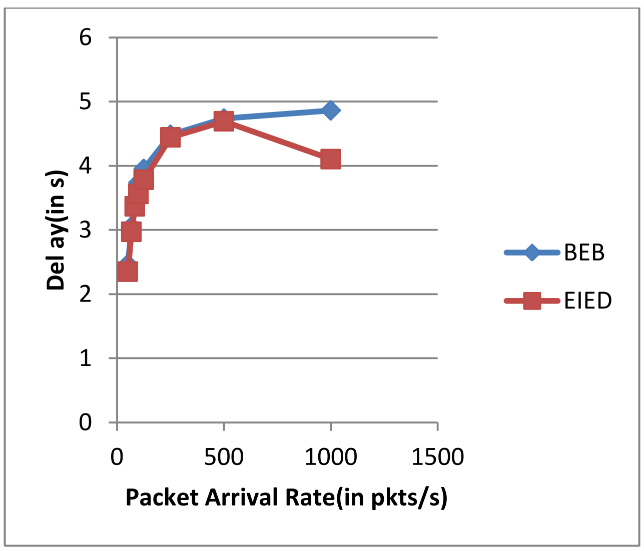

Fig 11: Packet Arrival Rate vs. delay (n=15)

n=15 , r_i =5 and r_d =7

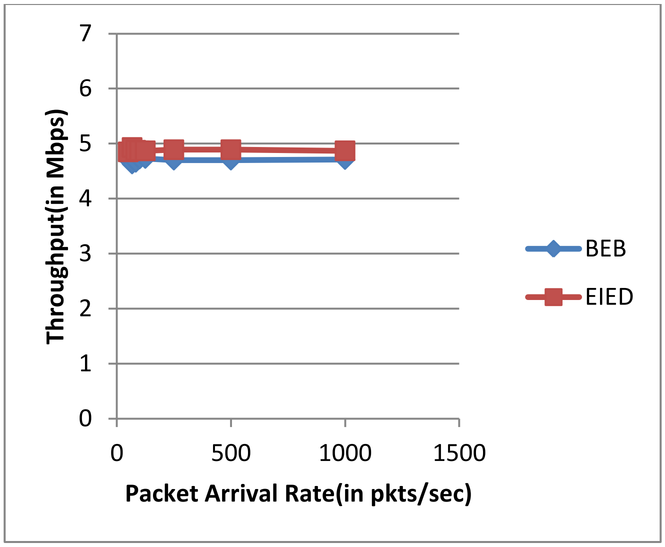

Fig 12: Packet Arrival Rate vs. throughput (n=25)

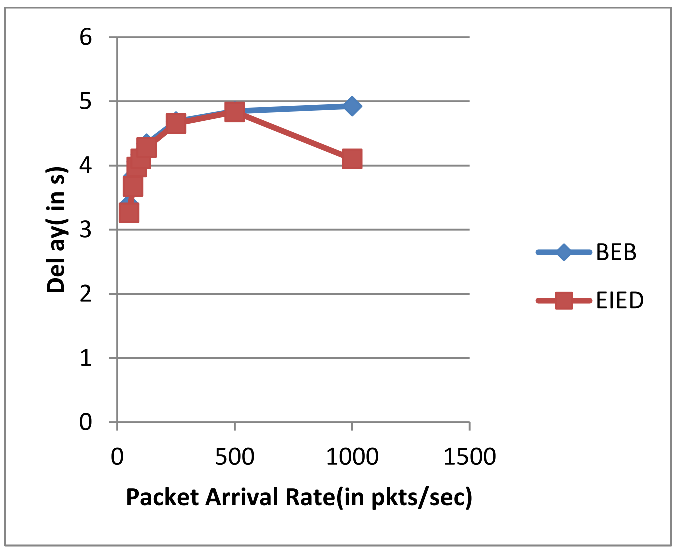

Fig 13: Packet Arrival Rate vs. delay (n=25)

$n=25$, $r_i=5$ and $r_d=7$

4.3 Inferences

While considering throughput it has been observed in all the three cases that all most in every case a better throughput was obtained in EIED than BEB. Also There is a decrease in delay in EIED as compared to BEB.

Approximately 40 combinations of values of ri and rd for each of the three packet arrival rates 1000µs/packet(Heavy Traffic), 10000µs/packet (Medium Traffic) and 20000µs/packet (Low Traffic) for n=5 , 15 & 25 each were simulated.

Some of the inferences are listed below.

- With ri and rd < 1 , the performance is very poor as expected.
- With ri =2 and rd = a large value , performance is equivalent to BEB.
- With ri =1.5 and rd =a value very close to 1, performance is equivalent to MILD.
- 2< ri and rd <20: Good performance.
- ri and rd with very large value like 25 or 30 performance decreases.

Inferences

For n=5	Result
Pkt arrival Rate=1000µs	On an average not much improvement of EIED over BEB.
Pkt arrival Rate=10000µs	On an average for equal ri and rd good improvement of EIED over BEB.
Pkt arrival Rate=20000µs	On an average not much improvement of EIED over BEB.

Table 7: Inference from various simulations (for n=5)

For n=15	Result
Pkt arrival Rate=1000µs	On an average for any ri and rd good improvement of EIED over BEB.
Pkt arrival Rate=10000µs	On an average for any ri and rd good improvement of EIED over BEB.
Pkt arrival Rate=20000µs	On an average for any ri and rd very good improvement of EIED over BEB.

Table 8: Inference from various simulations (for n=15)

For n=25	Result
Pkt arrival Rate=1000µs	On an average for any ri and rd very good improvement of EIED over BEB.
Pkt arrival Rate=10000µs	On an average for any ri and rd very good improvement of EIED over BEB.
Pkt arrival Rate=20000µs	On an average for any ri and rd very good improvement of EIED over BEB.

Table 9: Inference from various simulations (for n=25)

CHAPTER 5

5.1 Conclusion

WLAN is a vast area of research and many techniques are evolving in order to improve the WLAN network performance. MAC layer plays very important role because, with the increase in node numbers the network traffic has to be managed to minimize collisions. EIED has proved to be performing very well in basic access mechanism. It was also found to be performing well in RTS-CTS mechanism. It was proved by plotting various graphs.

But the values of ri & rd are highly customizable. So it is very difficult to find any pattern between values of ri & rd and network performance. Still the range of values for which EIED gives optimum performance were figured out.

Also it has been observed that for a heavily loaded network it is better to use EIED algorithm but for a light load even EIED does not give remarkable performance. Even it may be possible that for a certain data size and a certain packet arrival rate there may be a suitable value of ri & rd. The values of ri & rd were not exactly calculated but a relation may be found out between data size, packet arrival rate and values of ri & rd.

So it is concluded that a wide area of research is still open for values of ri & rd and EIED algorithm as a small change in back off algorithm affects the whole network performance drastically.

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